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(54) Transmission system minimizing interference in digital transmission.

(57) A method and apparatus for transmitting a digital television signal which provides audio, video and data packets alternating with training signals. In order to minimize interference to other systems which could occur due to the periodicity of the training signal, randomly selected training signals are inverted prior to combining them with the data packets.

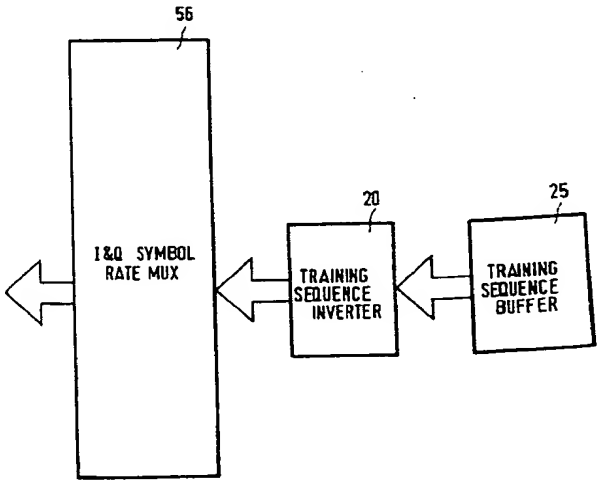

FIG.2

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The invention is related to a transmission system using training sequence portions periodically interleaved with data portions. The invention is also related to a transmitter and a transmission method for training sequence portions periodically interleaved with data portions.

Such system is described in European patent application No. 94201227.9 filed at May, 3, 1994 (Japanese Patent Application No. 94-93557, filed at May, 2, 1994)

Federal Communications Commission (FCC) and cable television testing organizations such as Cable Labs, have been evaluating digital television delivery systems in order to choose a new television "standard" which someday will replace NTSC in the United States. These systems all involve digital coding and data compression techniques, for example those utilizing the MPEG algorithm or variations thereof. Such systems utilize other digital compression schemes, for example MUSICAM, to digitally code audio.

The aforementioned patent application describes a method and apparatus for providing a single carrier QAM television signal which emulates the reception characteristics exhibited by audio and video in conventional analog television systems by using multiresolution signal constellations or by time-division multiplexing different constellations to prioritize the transmission of portions of a television signal.

In digital data transmission systems information is coded into data bits and a modem transmitter encodes groups of bits into symbols for transmission at a prescribed signalling rate. The analog transmission channels usually introduce linear amplitude and phase distortion to the transmitted signal as well as multipath. This distortion can cause an overlap of received symbols known as intersymbol interference (ISI). Such distortion can be compensated for by using an adaptive digital equalizer in the modem receiver to eliminate ISI caused by channel impairments. These equalizers require rapid, accurate and dependable estimation of the characteristics of the transmission channel in order to provide for fast start-up equalization. As described in the above mentioned patent application training sequences are embedded in the data stream to achieve the periodic equalization.

The aforementioned patent application describes a data stream which comprises, in addition to a main header packet comprising a "long" training sequence, additional headers each comprising "short" training sequences.

The addition of a "short" training sequence is useful for example, to compensate for mismatch caused when multiple receivers are connected to a cable system tap through a splitter. For example, a digital set top converter which might be initially used to receive digital television broadcasts by converting them to NTSC would be coupled to an analog NTSC TV set by a splitter. The "return loss", or equivalently the amount of signal reflected by the tuner in the analog set varies tremendously and therefore the digital converter may see a significant variation in the channel characteristics due to coupling through the splitter. This variation may occur so quickly that it cannot be tracked by the steady state adaptation mechanism of the demodulator in the set top converter. The demodulator's equalizer will therefore have to be reinitialized for the new channel characteristics and this can only happen after the demodulator receives the next training sequence. However it is not necessary to use the "long" training sequence normally used to adapt during power up or channel flipping. We can assume that the demodulator timing and frequency synchronization is undisturbed, so that it is only necessary to send a "short" training sequence to account for disturbances by other devices attached through splitters to the same cable.

Where training sequences (for example the "long" and "short" sequences of the aforementioned patent application) are periodically embedded in the data stream, repetitive patterns occur in the time domain and tone effects can result in the frequency domain. This can lead to RF and harmonic interference with other systems, for example NTSC television signal on "simulcast" co-channel. The object of the instant invention is to avoid or minimize such interference.

Therefor the invention provides a transmission system for transmitting a time multiplexed digital signal comprising data portions and training signal portions comprising a transmitter coupled via a transmission channel to a receiver, said transmitter comprising means for forming a plurality of data portions from a source of information, means for forming a plurality of training signal portions by inversion of selected training signals from a source of training signals, and means for time multiplexing said data portions and said training signal portions so as to form said time multiplexed digital signal.

The instant invention comprises a method and apparatus for inverting the logical state of the bits of selected training sequences in order to avoid periodicity and thereby minimize interference to other systems.

Preferably the selection of the training sequences to be inverted (pseudo) randomly.

Figure 1 describes a data stream wherein data packets are interspersed periodically with training sequences;

Figure 2 is a block diagram of the invention;

Figure 3 describes the data stream of Fig. 1 after processing the training signals in accordance with the invention;

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Figure 4 is a block diagram of the transmitter of the aforementioned patent invention which can be modified in accordance with the instant invention; and

Figure 5 is a block diagram of the training signal inverter.

Figure 1 describes a data stream in the form of data packets 15 (e.g. audio and video information packets) periodically interspersed with training sequences 10. Since the aforementioned patent application fully discusses the uses and implementation of training sequences in data streams, this information will not be discussed in great detail herein.

It is to be understood that each data packet 15 can comprise either audio or video information, or a combination of both, but is not limited to this type of data. As discussed in the aforementioned patent application, is also to be noted that digital data carrying information with different degrees of priority (i.e. need for robustness) can be contained in respective data packets 15, each with a rate sequence defining its respective signal constellation appended thereto.

A sequence as defined herein denotes a sequence of bits which can represent one or more pieces of data and/or a digital code word.

The previously mentioned patent application describes preferred training signals which exhibit a constant amplitude and zero aforementioned. These training signals are known in the art as CAZAC sequences.

As described in said patent application, periodic CAZAC training sequences in a one-way data transmission system can be used with alternation sequences for synchronization and packet detection. Although not shown in the figures, it is to be understood that a "training sequence" 10 can be either a training sequence alone, or a training sequence preceded by an alternation sequence.

The training sequence 10 is disposed within the data stream periodically to ensure that receivers can always receive a training sequence within a short time after being powered up, or upon switching channels. As shown, each training sequence 10 is identical in phase to the adjacent training signals. This periodicity in the placement of training signals can create RF interference which can disturb other systems, for example television programming on adjacent co-channel "taboo" channels. These channels will be used for providing conventional television when digital HDTV broadcasting, using such training signals, is implemented. Such periodicity can be minimized, or avoided altogether, however by changing the phase of alternating ones of said training signals 10 in accordance with the instant invention.

Figure 2 shows a block diagram of a preferred embodiment of the invention which can be used in conjunction with the transmitter which is part of the aforementioned patent invention and which is shown in Fig.4.

I & Q symbol rate multiplexer 56, as is more fully described in the aforementioned patent application, formats the data stream described in Figure 1 by time multiplexing training sequences (for example training sequences provided by "short" training sequence generator 52), and data packets 15 (for example from symbol to I and Q converter 46), under the control of system timing and control means 64. The training sequence provided by training sequence buffer 25 is fed to training sequence inverter 20. As described in more detail below in conjunction with Fig. 5, training sequence inverter 20 acts to aperiodically (e.g. randomly) invert selected ones of said training sequences in order to avoid the periodicity which results in the undesired interference. The inversion of a sequence, in terms of complex representation, represents a 180 degree rotation which will not effect the operation of the training sequence in their use with known algorithms for equalizer training. The training sequence processed in accordance with the invention is then fed to I & Q symbol rate multiplexer 56.

Fig. 3 describes the data stream of Fig. 1 after it emerges from training sequence inverter 20. Three training sequences are shown and one of them, 10^*, is shown inverted with respect to the training sequences 10, thus interrupting the periodicity which otherwise would exist.

Fig. 5 is a block diagram of training sequence inverter 20. The training sequence from training sequence buffer 25 is provided at training sequence input 29 and provided to one input of switch 35. The training sequence is also provided to inverter 30 which in turn provides an inverted training sequence to a second input of switch 35. The switch 35 can select as the output to I & Q symbol rate multiplexer 56, either the training signal from input 29 or its inverted version provided by inverter 30. The selection of the switch output is under the control of a pseudorandom generator 40, which will output, for example, either a "1" or a "0" on a pseudo random basis, which will control the selection of switch output where a "1" will cause the switch to couple the first input (training sequence) to the switch output, and a "0" will cause the switch to couple the second input (inverted training sequence) to the switch output.

The activation of pseudo random generator 20 is under the control of system timing and control circuit 64 which provides the necessary timing to provide for the necessary switching to occur between training sequences (e.g. during data pack-

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ets). The system and timing control circuit 64, discussed in more detail in the aforementioned patent application, can be easily designed by one skilled in the art of digital logic design.

The foregoing disclosure and description of the invention is illustrative and explanatory thereof and various changes in the details of the embodiments shown may be made within the scope of the appended claims without departing from the spirit of the invention.

Claims

1. Transmission system for transmitting a time multiplexed digital signal comprising data portions and training signal portions comprising a transmitter coupled via a transmission channel to a receiver, said transmitter comprising means for forming a plurality of data portions from a source of information, means for forming a plurality of training signal portions by inversion of selected training signals from a source of training signals, and means for time multiplexing said data portions and said training signal portions so as to form said time multiplexed digital signal.

2. Transmission system according to claim 1, characterised in that the inversion means are arranged for randomly selecting the training signal portions to be inverted.

3. Transmission system according to claim 1 or 2, characterised in that the transmitter comprises a modulator for quadrature amplitude modulating said data and training signal portions on a carrier.

4. Transmission system according to claim 1,2 or 3, characterised in that said information is a video signal.

5. Transmission system according to claim 4 characterised in that said data portions also comprise an audio signal.

6. Transmitter comprising means for forming a plurality of data portions from a source of information, means for forming a plurality of training signal portions by inversion of selected training signals from a source of training signals, and means for time multiplexing said data portions and said training signal portions so as to form said time multiplexed digital signal.

7. Transmitter according to claim 6, characterised in that the inversion means are arranged for randomly selecting the training signal portions to be inverted.

8. Transmitter according to claim 6 or 7, characterised in that the transmitter comprises a modulator for quadrature amplitude modulating said data and training signal portions on a carrier.

9. Method for transmitting a time multiplexed digital signal comprising data portions and training signal portions, said method comprising forming a plurality of data portions from a source of information, forming a plurality of training signal portions by inverting selected training signals from a source of training signals, and time multiplexing said data portions and said training signal portions so as to form said time multiplexed digital signal.

10. Method according to claim 9, characterised in that the training signal portions to be inverted are randomly selected.

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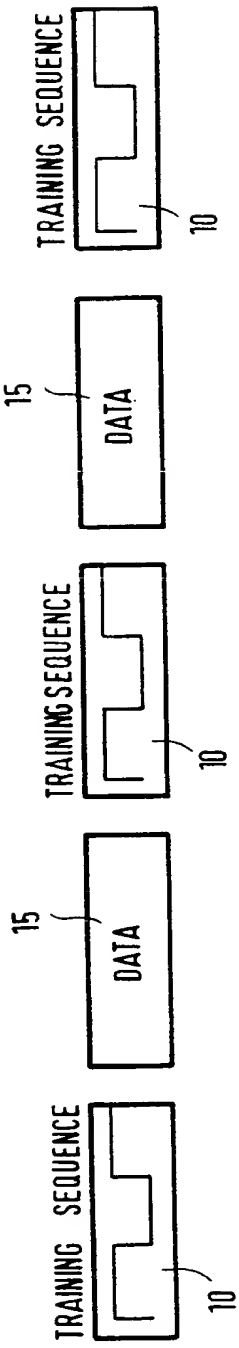
TRAINING SEQUENCE
10
15
DATA
TRAINING SEQUENCE
10
15
DATA
TRAINING SEQUENCE
10

FIG.1

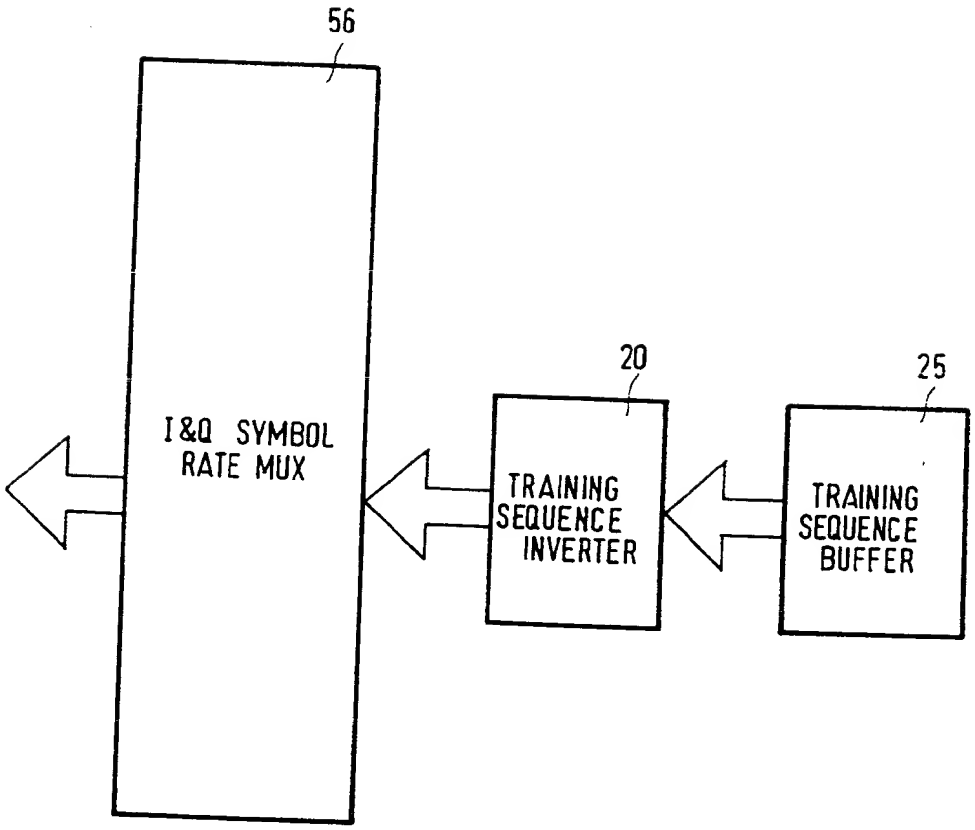
56
I&Q SYMBOL RATE MUX
20
TRAINING SEQUENCE INVERTER
25
TRAINING SEQUENCE BUFFER

FIG.2

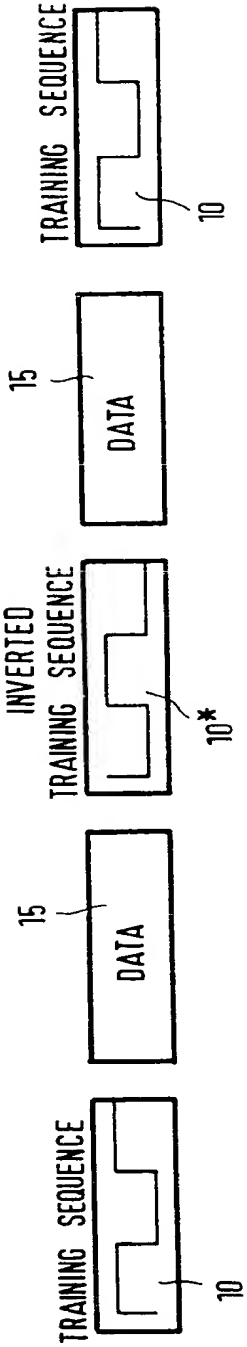
TRAINING SEQUENCE
10
15
DATA
INVERTED
TRAINING SEQUENCE
10*
15
DATA
TRAINING SEQUENCE
10

FIG.3

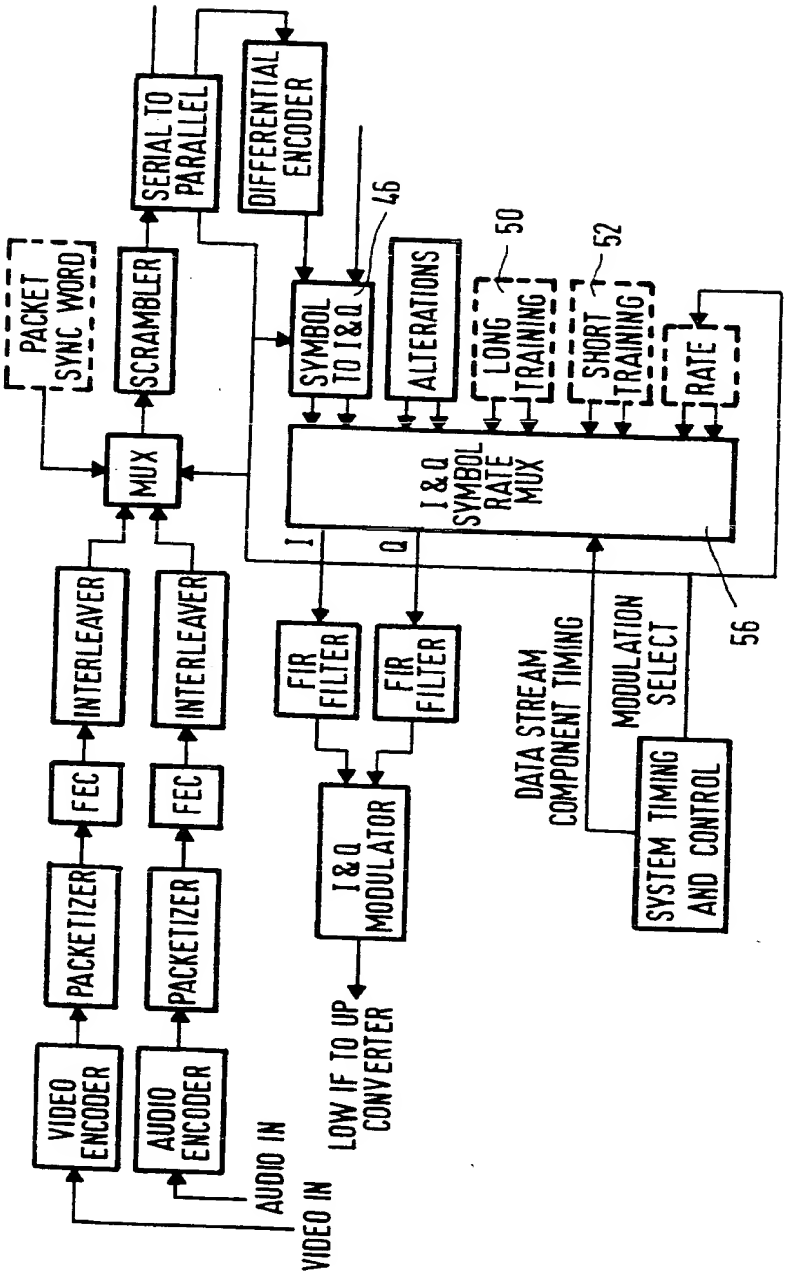

FIG. 4

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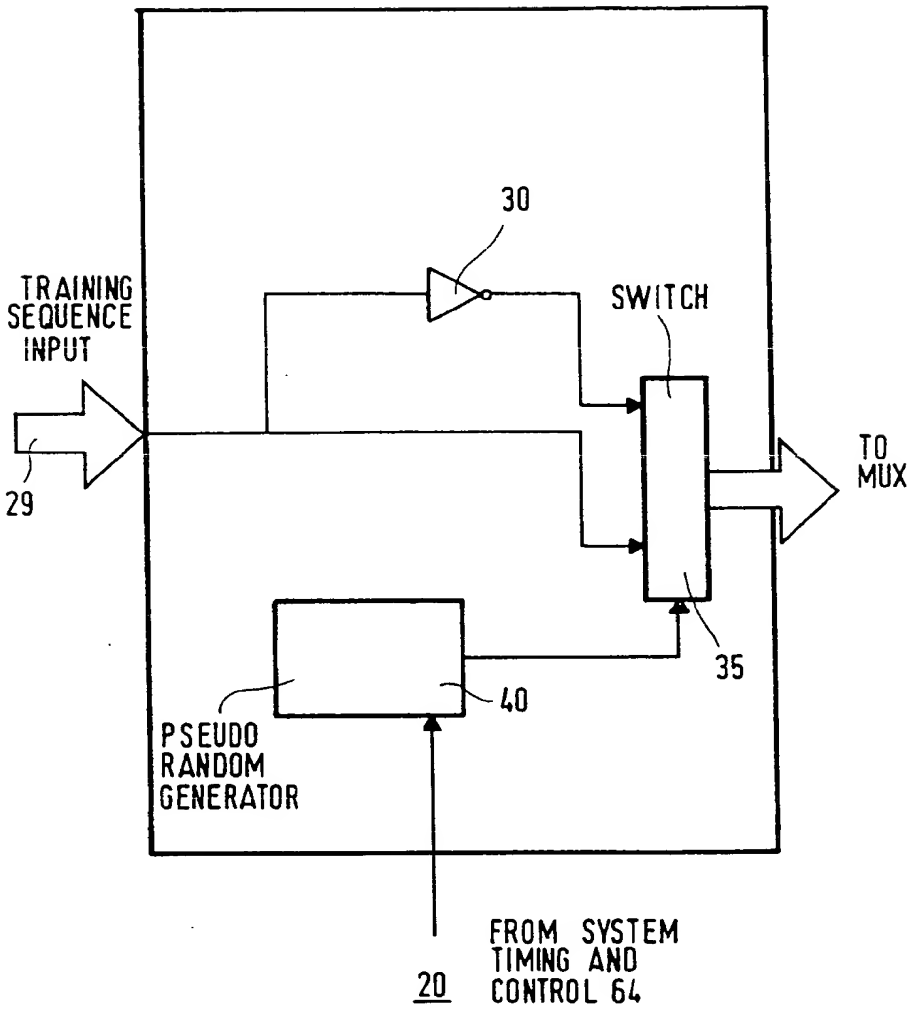
TRAINING SEQUENCE INPUT
29
30
SWITCH
TO MUX
35
40
PSEUDO RANDOM GENERATOR
20
FROM SYSTEM TIMING AND CONTROL 64

FIG.5

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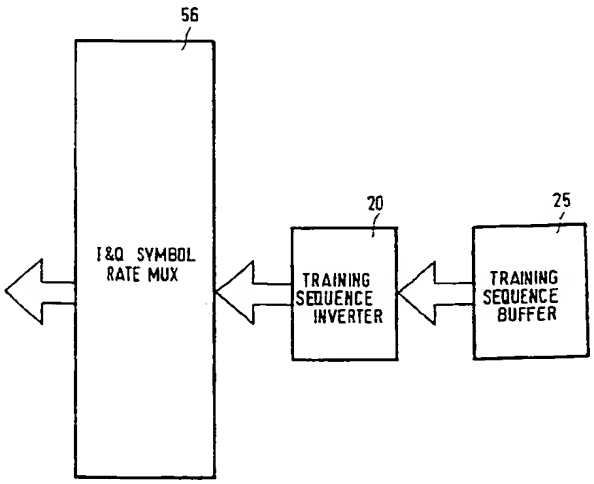

FIG.2

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EUROPEAN SEARCH REPORT

Application Number
EP 94 20 2879

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	DE-A-34 17 867 (RICOH KK) 15 November 1984 * page 4, line 12 - page 6, line 3 * * page 10, line 11 - line 16 * * page 14, line 9 - line 22 * * figures 1,2,6 *	1-4,6-10	H04N7/24
A	PATENT ABSTRACTS OF JAPAN vol. 16 no. 254 (E-1213) ,9 June 1992 & JP-A-04 054735 (OKI ELECTRIC INDUSTRIAL COMPANY LTD) * abstract *	1,6,9	
A	IBM JOURNAL OF RESEARCH AND DEVELOPMENT, vol. 27, no. 5, September 1983 NEW YORK US, pages 426-431, MILEWSKI 'Periodic Sequences with Optimal Properties for Channel Estimation and Fast Start-Up Equalization' * page 426, right column, paragraph 2 - paragraph 3 * * page 429, left column, paragraph 6 - page 430, left column, paragraph 2 *	1,6,9	
A	US-A-4 577 334 (BOER JAN ET AL) 18 March 1986 * column 1, line 26 - line 37 * * column 3, line 39 - line 62 * * figure 2 *	1,3,6,8,9	
A	US-A-5 122 875 (RAYCHAUDHURI DIPANKAR ET AL) 16 June 1992 * column 4, line 3 - line 12 * * figure 11 *	3-5,8	

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TECHNICAL FIELDS SEARCHED (Int.Cl.6)

H04N

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	3 July 1995	Dippel, U

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EUROPEAN SEARCH REPORT

Application Number
EP 94 20 2879

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	US-A-4 320 517 (GODARD DOMINIQUE N ET AL) 16 March 1982 * column 1, line 18 - column 2, line 43 * * column 8, line 66 - column 9, line 15 * * figure 2 * -----		

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